National Aeronautics and Space Administration

System Failure Case Studies

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ROCKY MOUNTAIN DEATH TRAP

Fifteen smokejumpers leapt from a C-47 aircraft on a hot, dry August afternoon in 1949 to engage what was believed to be a routine forest fire burning along the south ridge of the Mann Gulch, a steep, narrow, valley, situated directly east of the Missouri River. Over the next 90 minutes a complex, confusing, and heroic struggle ensued as the fire, fanned by high winds and downdrafts spread in unexpected ways, cutting off firefighters from their planned river escape path and roaring up the gulch with a wall of flame, superheated air and black boiling smoke. In the end, 13 of the firefighters lost their lives. This tragic event dealt a devastating blow to the Smokejumper program and drastically changed the way the Forest Service analyzes hazards and how its fire fighters are trained, equipped, led, and deployed.

BACKGROUND

The US Forrest Service was established by President Theodore Roosevelt in 1905, 100 years after Captain Meriwether Lewis and his party camped out just below Mann Gulch at the mouth of Merriwether Canyon. The Forest Service began using aircraft to spot fires and direct ground-based firefighters in 1925, and established the Smokejumpers as an elite firefighting organization capable of rapidly deploying crews on forest fires located in inaccessible areas.

The Mann Gulch smokejumpers were based in Missoula, Montana, approximately 100 miles to the west of the gulch, and used C-47 aircraft to reach fires. Smokejumpers were elite corps of young men, fit, tough, confident, and savvy in the ways of the forestry and backcountry work. These attributes are indeed desirable and essential for the job but may also lead to overconfidence or hubris. The management philosophy of the Forest Service embraced a low overhead – low cost organizational strategy wherein a pool of 150 smokejumpers was used in a rotational fashion to deploy on forest fires. This approach resulted in teams of strangers who often did not know each other very well and often did not know their leaders.

Mann Gulch is a narrow valley, only two-and-a-half miles in length extending to the east of the Missouri River in the Gates of the Mountains Wilderness Area, 20 miles north of Helena, Montana. The south slope is moderately steep rising to a ridgeline shared with Merriwether Canyon to the south. The north slope is very steep, rising to a "reef" or ridgeline of often crumbling rock cutting through to Rescue Canyon to the north. The south slope was heavily timbered with slow burning, six to eight inch diameter Douglas fir and scattered ponderosa pine. The

The mouth of Mann Gulch.

Mann Gulch Forest Fire Takes the Lives of 13 Forest Service Firefighters

Proximate Causes:

- Unexpected winds carried the compact fire from the south ridge to the mouth of the gulch and lower north ridge, closing off both the planned attack and escape routes
- Steep terrain, strong up-gulch winds, and dry, fast burning fuel allowed the fire to move rapidly up the north ridge overtaking the firefighters

Underlying Issues:

- Inadequate overall smokejumper management approach
- Incomplete understanding of the prevailing weather conditions, terrain and likely fire behavior

lower part of the north slope was also heavily timbered but the upper regions were dominated by scattered trees and an abundance of fast burning cheat and bunch grasses.

What Happened

Conditions in Mann Gulch: August 5, 1949 was a day of record heat in Montana with a temperature of 97 degrees Fahrenheit recorded at Helena, 20 miles to the southwest. Winds were gusty and generally unsettled throughout the region with scatted thunderstorm activity.

At the mouth of Mann Gulch winds (from the south) were estimated to be approximately 25 miles per hour (mph) with gusts reaching 40 mph. The high temperatures and local drought conditions resulted in very low moisture content of the grass, shrubbery, and trees.

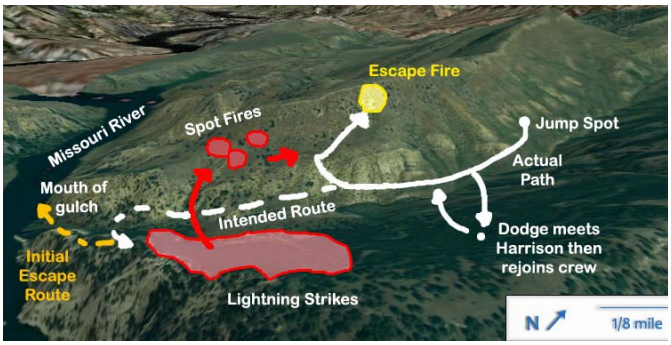
Fire Spotted: The fire in Mann Gulch began in the late afternoon on August 4, 1949 as a lightning induced "smoker," at three locations along the south ridge of Mann Gulch. Several observers identified the fire around mid-day on August 5.

Mann Gulch on August 5, 1949.

First Responder: Forest Ranger Jim Harrison, a former smokejumper and now the Forest Ranger at Meriwether Canyon, set out to engage the blaze. Ranger Harrison used his pick to scrape and cut a fire line to contain ground-fire migration.

The Flight and Drop: A team of smokejumpers was dispatched from Missoula and began the drop around 3:10 pm. When arriving at a fire site the aircraft would typically circle at approximately 1200 feet above the terrain with pilot, foreman (crew chief), and spotter, evaluating the terrain, the fire behavior, and determining the safest drop location. Heavy turbulence and downdrafts caused the pilot, spotter, and foreman to decide on a drop from a higher altitude (2000 feet) to ensure the safety of the smokejumpers. As a result the fire-fighting gear was spread over a large area and it was nearly 5:00 pm by the time the team had gathered all their equipment.

The Plan: The plan was to proceed down the north slope of Mann Gulch to the protection of the Missouri River as an escape path, then attack the fire from its rear flank. Surviving crew member Robert Sallee later recalled that they "took a look at the fire and decided it wasn't too bad." The second path of retreat was considered to be back up the gully to the north ridge line, often a 75% grade.



Fire leapfrogged to the north rim of the gulch, cutting off both the primary attack plan and escape route.

Descent into Mann Gulch: While Foreman Dodge went to meet Ranger Harrison the smokejumpers led by second in command Helman gathered their gear and began their descent down Mann Gulch shortly after 5:00 pm. At 5:40 pm Dodge and Harrison rejoined the crew and together they moved further down the gully.

Proximate Causes

Blow-up / Down-draft or Vortex - Pivotal Event: Unknown to the firefighters, around 5:30 pm "spot fires" appeared at the mouth and on the northern slope of Mann Gulch, effectively eliminating the path to the safety of the river. Multiple theories exist for how this occurred. One theory points to a possible down-draft from a thunder storm cell in the area, while the other suggests that turbulent air flow breaking over the crest of the ridge between Mann Gulch and Meriwether Canyon lifted and spread burning embers along the upper reaches of the south slope.

The flame wall accelerated to between 600 and 700 feet per minute

Turnaround and Fatal Race: At 5:45 pm Dodge, alarmed by the sudden appearance of billowing smoke ahead brought the team to a halt and gave orders to reverse direction back up the gulch. After eight minutes Dodge ordered the men to drop all the gear they were still carrying. The wall of flame was only 200 to 250 yards away and moving at 200 to 250 feet per minute through the last of the heavy timber, assisted by a trailing wind and steep slope. It has been estimated that during the final minutes, when the flame reached the area predominately consisting of dry grasses the flame wall accelerated to between 600 and 700 feet per minute.

Intervention - Escape Fire: Recognizing the futility of the race, foreman Dodge quickly lit a rescue fire or intentional burn zone as a last ditch effort to save the team.

Discipline Lost: As Dodge implored the team to take refuge in the charred grass all discipline shattered and it was literally every man for himself. Dodge lay face down in the burnt grass and survived as the fire storm raged over him.

As a result of the deaths in Mann Gulch, new personal protective equipment was developed at the Missoula center for smokejumpers.

Death on the Run: Eleven men lost the race up the gully, probably dying from asphyxiation as patches of unburned grass were found under each body.

Death at the Rim Rock: Four men turned up the steepest slope to seek the refuge of the north ridge. Two men, Salee and Rumsey miraculously found passage through the crumbling rim-rock. The third and fourth, Helmen and Sylvia were both overtaken by the flames and died.

Underlying Issues

Poor Smokejumper Organizational Management Approach

The rotational pool approach may have saved money but actually served to weaken safety and performance by putting teams of strangers, or at best acquaintances, in safety critical situations in which they must rely upon each other.

Lack of Team Discipline and Inadequate Team Training: One can argue that each individual on a team of strangers, in a life or death situation, will act on his own. Clearly the lack of team training, identity, trust, and discipline can be cited as an underlying cause. Dodge's escape fire may have saved all of their lives had they listened to him. A corollary to the first point is lack of operational team training. The Forest Service training approach did not provide the context for operational team development.

Ignored Leadership: When Dodge ordered the men to abandon their heavy tools and try to escape the fire, the organizational structure disintegrated. With this ad hoc group, it was clear that under stress, they did not respect the direction of the leadership which resulted in individual decision making and eventually, significant casualties.

Failure to Communicate Efficiently: Poor communication among teammates during critical decisions was also obviously an issue. If Dodge had been able to communicate over the noise of the roaring firestorm he may have been able to persuade the men to take cover in the escape fire zone. Similarly, though not a determinant on the outcome, the team lost its only radio when the parachute failed to open during the drop. Having a working radio for communication with the home base, might have hastened the rescue efforts.

Incomplete Understanding of Interactions of Wind, Fuel, Terrain & Fire behavior:

Invariably, principal participants in this case took risks based on their experience and best information available. Managers on the scene did indeed define an escape route as part of their strategy for fighting the fire: once they reached the river and flanked the fire they would have a clear and easy (downhill) retreat path to the Missouri River. However, they did not anticipate the fire jumping across the gulch and cutting off access to *both* their intended attack and escape routes. The journey from the drop zone to the river had no viable contingency plan as the retreat path up to the ridge was just too steep, rocky, and intrinsically dangerous when one, in hindsight, considers the abundant, dry, fast-burning grass cover and the high, gusty winds blowing up the narrow canyon. In planning both their attack and retreat strategies, the team leaders did not give adequate consideration to the dynamic nature of fire and weather conditions.

ALL DISCIPLINE SHATTERED AND IT WAS LITERALLY EVERY MAN FOR HIMSELF

Aftermath

The Mann Gulch fire was a wake up call for the U.S. Forest Service, similar in many ways to the impact losing the THRESHER (SSN-593) had on the U.S. Navy's, nuclear submarine program. In the 10 year history of the smokejumpers prior to Mann Gulch, they had fought 52,000 fires without losing a single man. The disaster spurred the US Forest Service to implement numerous changes in organization, operational training, and risk management protocol, and motivated the development of fire science laboratories at Missoula Montana and Macon Georgia.

The need for safety zones and escape routes was re-emphasized in training of all smokejumpers and all wildfire fighters. In addition, training increasingly incorpo-

rated more complete information on fuels, terrain, and wind/fire interactions. Increased emphasis on communication technology has further improved tactical and strategic planning for firefighting operations. The Mann Gulch firefighters wore blue jeans, long sleeved cotton shirts, and baseball caps. Firefighters now wear helmets, fireproof clothing, and carry reflective, metallic-coated fire shelters.

In addition, the Mann Gulch fire led to the evolution of "The Ten Standard Fire Orders"

- Fight fire aggressively but provide for safety first
- Initiate all actions based on current and expected fire behavior
- Recognize current weather conditions and obtain forecasts
- Ensure instructions are given and understood
- Obtain current information on fire status
- Remain in communication with crew members, your supervisors, and adjoining forces
- Determine safety zones and escape routes
- Establish lookouts in potentially hazardous situations
- Retain control at all times
- Stay alert, keep calm, think clearly, act decisively

The safeguards established after Mann Gulch helped the Forest Service forestall similar tragedies for almost 45 years. Until in July 1999, the South Canyon Fire on the steep slopes of Storm King Mountain, Colorado took the lives of 14 firefighters.

NASA Applicability

Working as a Unified Group: Teamwork, communication, training, and trust are all important themes that need continual emphasis for crews involved in hazardous ground and space operations. The South Canyon Fire mishap serves as a reminder that neglecting process, organizational, technology, and management excellence can lead to tragedy in inherently hazardous undertakings. Continual vigilance, team training, operational process discipline and safety critical decision making can indeed help NASA forestall serious failures or mishaps.

Understanding Operating Environments: The NASA and space exploration communities can take away reminders about the need to understand operating environments and the potential for dynamic changes (off nominal behavior) that will test the rigor and fidelity of planning and design. In the case of the Mann Gulch fire, the accident scenarios were not fully thought through. After having fought 52,000 fires, a few simple calculations would likely have allowed them to understand that hot, dry conditions with 40mph winds could result in a very fast moving fire. At NASA we must ask ourselves if we really understand the physics of possible failures and their consequences, in order to determine if risks have been properly mitigated.

Questions for Discussion

- Would you have stayed with smokejumper foreman Dodge in the hastily constructed safety zone or run for the ridge?
- Can you envision a similar or analogous critical decision – critical behavior scenario at your facility?
- Do you work with highly energetic systems, hazardous processes and/or materials whose behavior you do not fully understand?
- Has there been adequate training within your workgroup to prepare you for emergencies within your facility?
- Is adequate emphasis given to the operational planning, training and use of personal protective equipment in your hazardous operations? – in your routine laboratory or industrial activities?"
- Discuss the "Ten Standard Fire Orders" and their relevance (in principle) for your work group, your center, your program, and NASA in general.

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